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6. AUTHOR(S) Prof. Sanjay Krishna (PI)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Center for High Technology Materials, University of New Mexico, 1313 Goddard SE, Albuquerque NM 87106			8. PERFORMING ORGANIZATION REPORT NUMBER Number 1	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NE 875 N. Randolph St, Ste 325 Arlington, VA 22203 Dr. Donald Silversmith			10. SPONSORING / MONITORING AGENCY REPORT NUMBER AFRL-SR-AR-TR-07-0033	
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13. ABSTRACT (Maximum 200 words) An imaging polarimeter captures an image with both the intensity and the average polarization state recorded for each pixel. A polarimetric image has more information than a simple intensity image and improves remote sensing and automatic target recognition. The current technology of imaging polarimeters cannot reliably measure high-spatio-temporal polarization or high-spectral-resolution polarization of a moving scene; the camera reports huge errors at the boundaries of objects in the scene or trades-off spatial and spectral resolution to achieve faster measurements. The aim of the proposed project is to realize a new optoelectronic device that completely and instantaneously measures the incident light's polarization for a narrow wavelength band in a single physical pixel. We have undertaken theoretical modeling of the Polarimeter in a Pixel and undertook one round of fabrication of the device. Although the device exhibited good mid infrared absorption, the electrical characteristics were poor due to residual Silicon Nitride. We are requesting follow on funding to undertake experimental studies on this project in collaboration with AFRL/VSSS.				
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CONTRACT/GRANT NUMBER: FA9550-04-1-0396

REPORT TITLE: *REPORT ON POLARIMETER IN A PIXEL*

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SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

Sincerely,

FINAL Report

Period: 12/01/03-11/30/06

By

Prof. Sanjay Krishna, CHTM

AFOSR Award #: FA9550-0401-0396

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Statement of Objectives:

The aim of the proposed project is to realize a new optoelectronic device that completely and instantaneously measures the incident light's polarization for a narrow wavelength band in a single physical pixel. This could be used for applications that involve snap shot imaging with a narrowband active illumination.

Project Scope and Status:

This seed project, which began on June 1st 2004, is intended for three years. The initial emphasis of the project was on the electromagnetic modeling of the polarimeter and optimization of the design. Then quantum well infrared photodetector were grown. A spectral element based model was developed to determine the various eigenstates and eigenfunctions in the QW heterostructure. After the optimization of the growth parameters, the samples were fabricated into QWIPs. The tested material was sent to Dr. Liao at MIT Lincoln labs for wafer fusion. These were then characterized in collaboration with Dr. Cardimona's group at AFRL. Extensive computer modeling and heterostructure engineering will then be undertaken in the last year to optimize the performance of the devices.

Progress Update

We are working in close collaboration with Dr. Dave Cardimona's group at AFRL. Dr. Tveta Apostolova, a post doctoral research scientist, in Dr. Cardimona's group spent over six months at CHTM learning the processing of the polarimeter in a pixel. A process traveler was developed. However due to extraneous circumstances, Dr. Apostolova, moved from AFRL. Recently, Dr. Bill Glass, from AFRL/VSSS has taken over the project. Due to the limited funding on this project, we could only undertake one round of fabrication of the device, which yielded poor electrical characteristics due to residual Silicon Nitride. We have requested support from AFOSR for a collaborative proposal with AFRL/VSSS.

Detailed Progress:

In order to validate the principle-of-operation of the polarimeter in a pixel, we have developed a working electromagnetic model of the device using transfer-matrix techniques described in Andersson [AL91, AL92] and Wendler [WK99]. The code was written in GNU C++ on windows-based computers and is available upon request. Figures 1 and 2 show some results of this working electromagnetic model of the the proposed device. On the graph's ordinate, the fraction of incident light absorbed in the four quantum-well stacks respectively for 9.5 micron incident light. The abscissa of figure 1 shows the angle of linearly polarized incident light. The abscissa of figure 2 shows the phase lag between 0-degree polarized incident light and 90-degree polarized incident light. The phase lag smoothly changes the polarization from 45-degree linear to right circular to

135-degree linear to left circular. The graph demonstrates that the relative photocurrents from the four quantum-well stacks provide a means to measure the polarization of incident light.

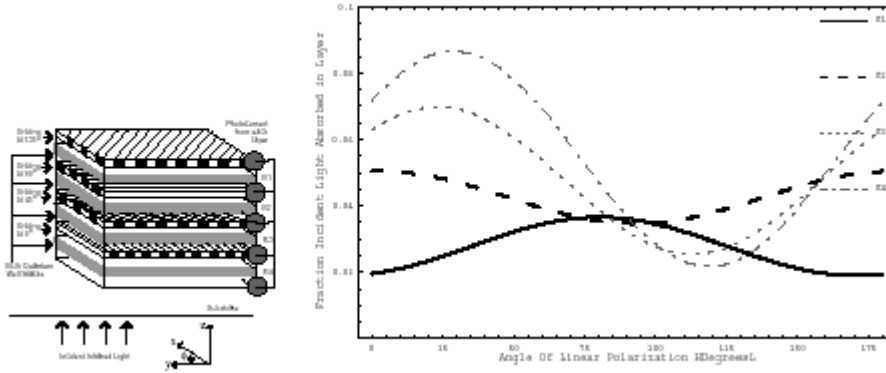


Figure 1: An example of the response from the four layers of the pixel-polarimeter as we rotate the polarization angle of the incident linearly-polarized light.

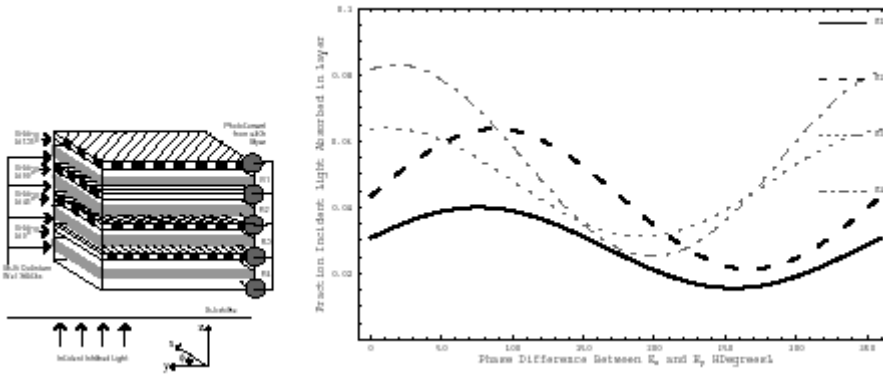


Figure 2: An example of the response from the four layers of the pixel-polarimeter to x polarized and y-polarized plane wave.

We have also developed a spectral element solver to investigate the bandstructure and density of states in quantum wells that will form the basis of the polarimeter. One of the inherent difficulties modeling quantum well infrared photodetectors (QWIPs) is that they are effectively open quantum systems. Since transitions are between bound states and current carrying continuum states, represented by non-normalizable eigenfunctions, one faces the problem

of to providing a physically meaningful and numerically efficient approximation to the continuum. Most numerical discretization methods lead to a domain truncation wherein the scattering states are locally approximated by bound states. The bound-to-bound (B to B) transitions are straightforward to compute as both eigenfunctions involved lie in the traditional Hilbert space. However, in order to compute the bound-to-continuum (B ! C) transition probabilities, the domain must be restricted to a finite interval which leading to “artificial quantization.” The continuum density-of-states (DOS), and momentum matrix elements (MME) of photoabsorption then scale arbitrarily with the domain size. We present an fast and e_icient method for computing the e_ective DOS and MME in quantum well structures through a spectral element discretization. It is shown that the continuum scaling problem is resolved through the introduction of a finite carrier lifetime function.

Publications/Presentations:

G. von Winckel, E. Coutsiyas and S. Krishna, “The Helmholtz Eigenproblem in Elliptical Domains using Spectral Tau-Method and Conformal Mapping”, International Conference on Spectral and High Order Methods, Providence, RI June 2004.

G. von Winckel, E. A. Coutsiyas and S. Krishna, “Spectral Element Modeling of Semiconductor Heterostructure’, Submitted to Journal of Applied Physics.

Mario Serna, “Polarimeter in a Pixel” SPIE Annual Meeting Denver August 2004.

Sanjay Krishna” Reconfigurable Sensors based on Quantum Confined Structures”, AFRL Reconfigurable Workshop, Feb 2007.